

Modeling an Energy-Intensive Economy in the Face of Uncertainty

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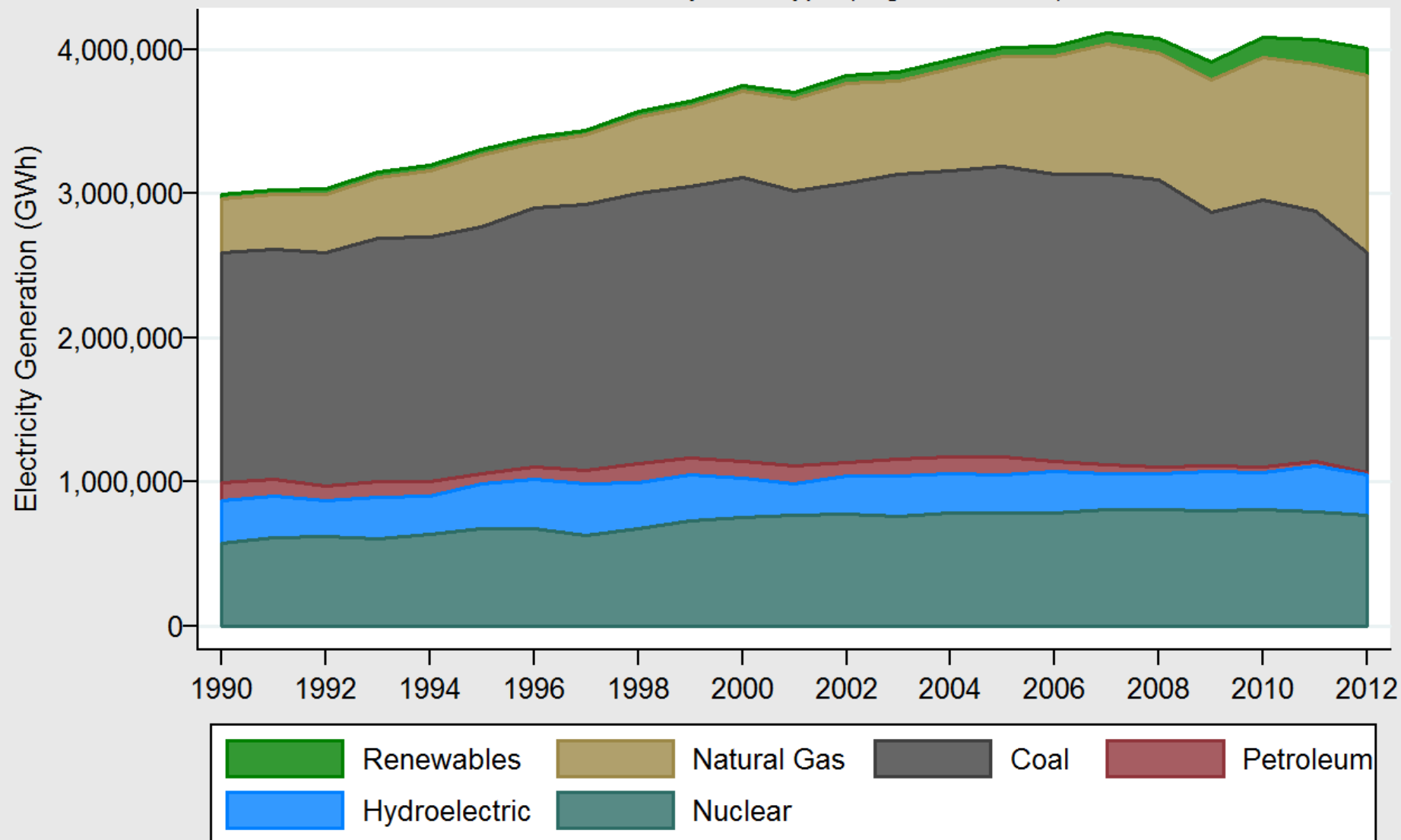
energy.ky.gov

Context

Electricity in Kentucky

United States Electricity Generation, 1990-2012

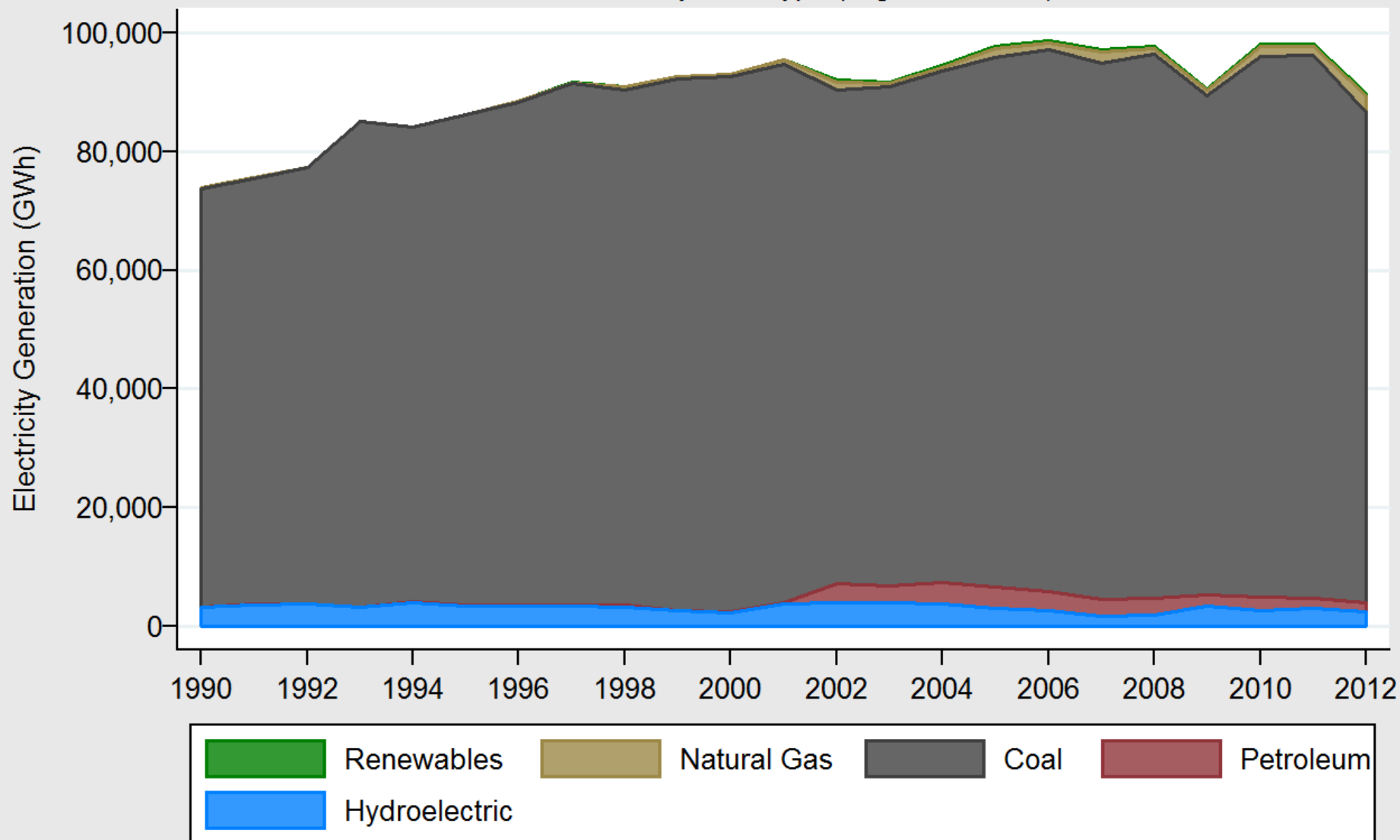
Generation by Fuel Type (Gigawatt Hours)



Kentucky Energy Database, EEC-DEDI, 2013

Kentucky Electricity Generation, 1990-2012

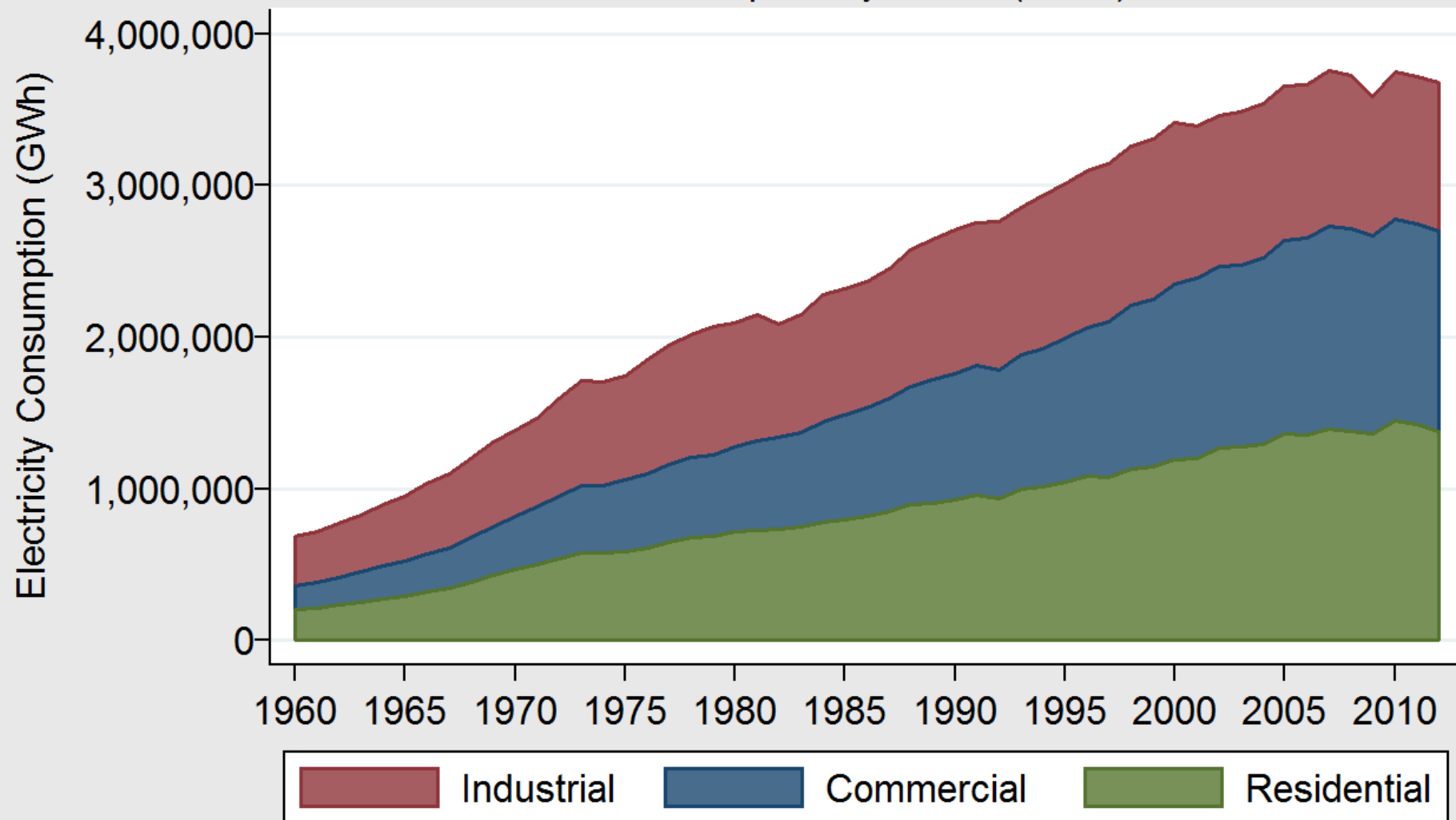
Generation by Fuel Type (Gigawatt Hours)



Kentucky Energy Database, EEC-DEDI, 2013

United States Electricity Consumption, 1960-2012

Consumption by Sector (GWh)

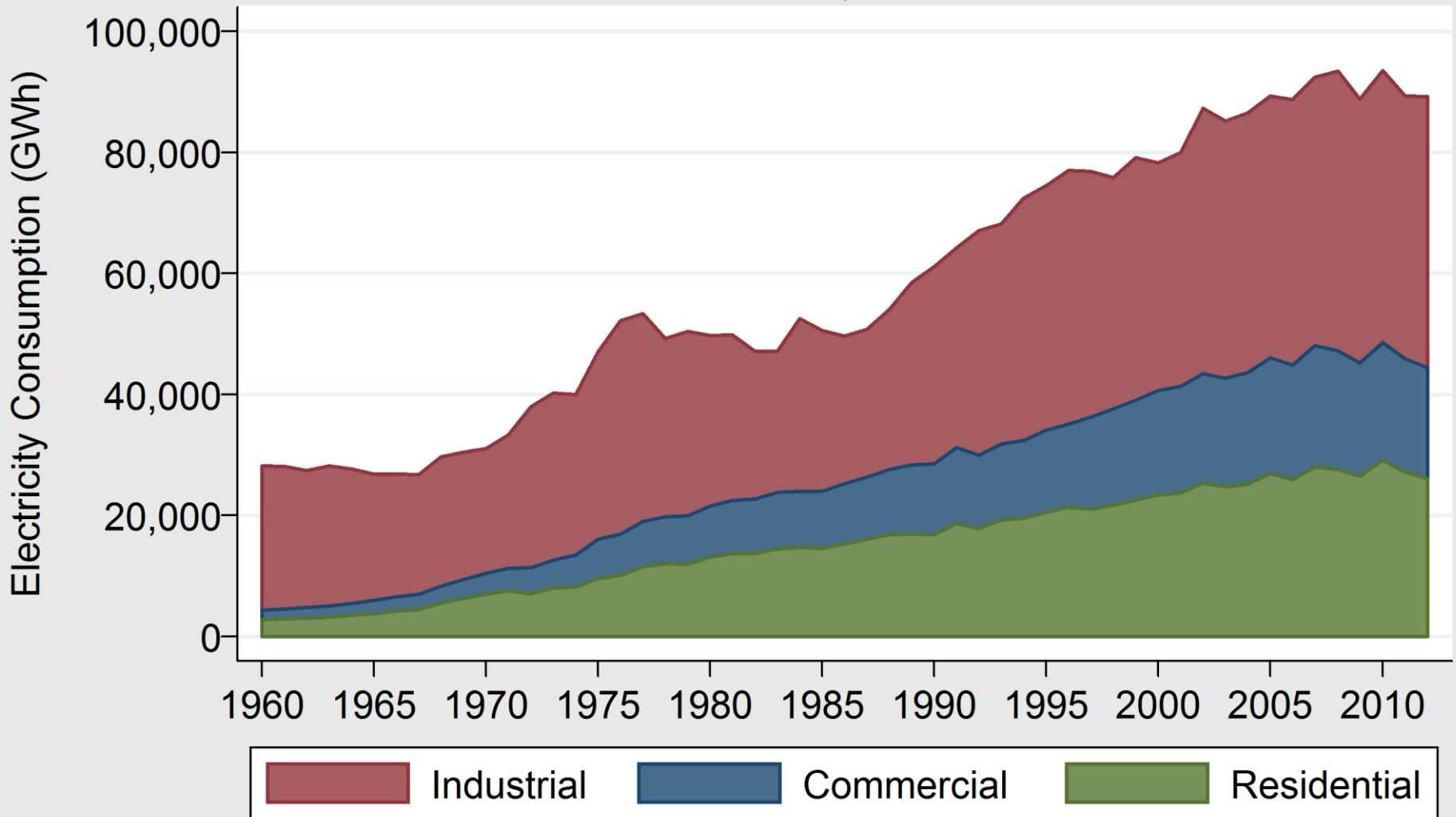


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826

Kentucky Electricity Consumption, 1960-2012

Consumption by Sector (GWh)

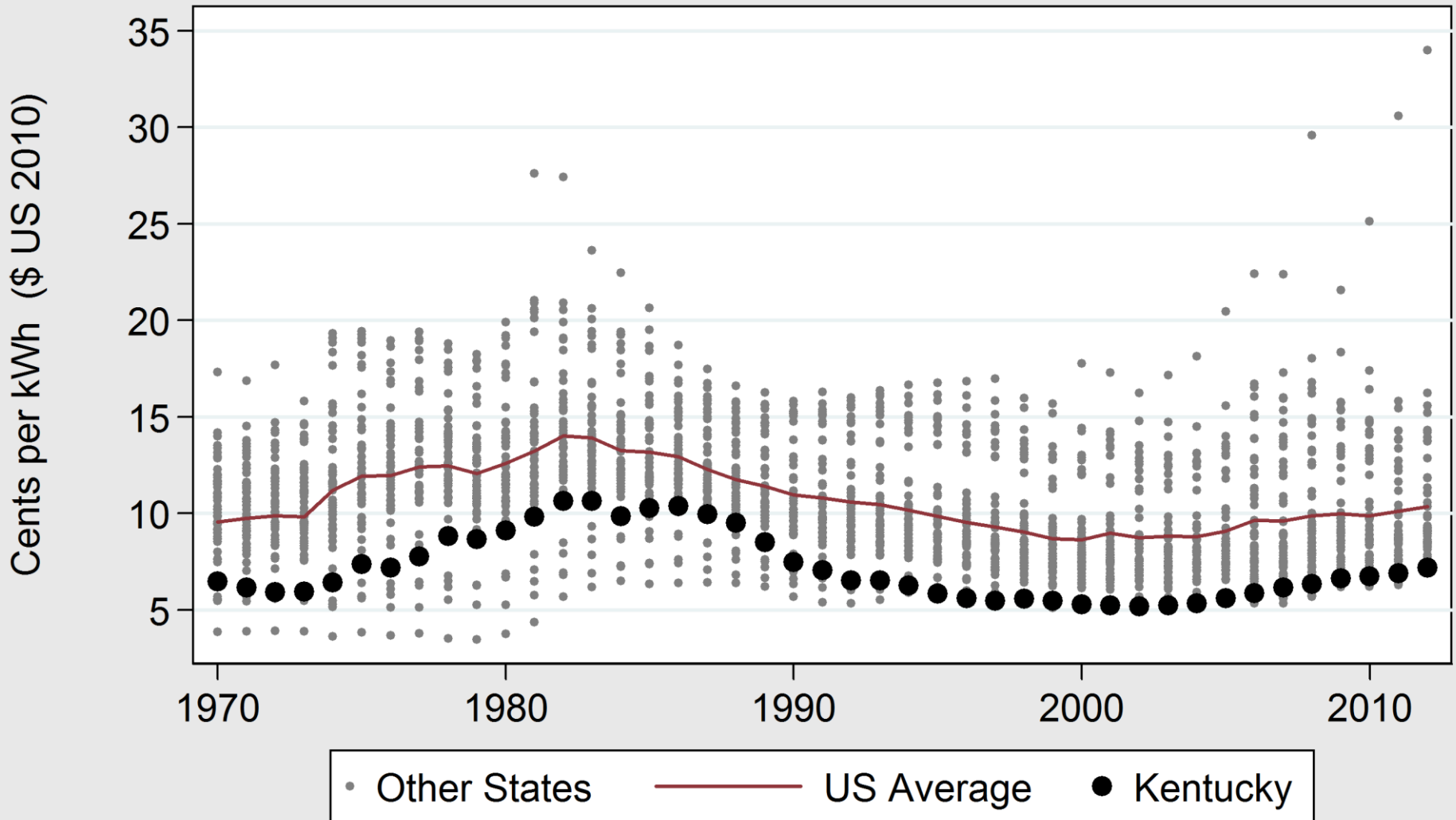


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826

Kentucky Average Real Electricity Price, 1970-2012

Kentucky vs. the United States

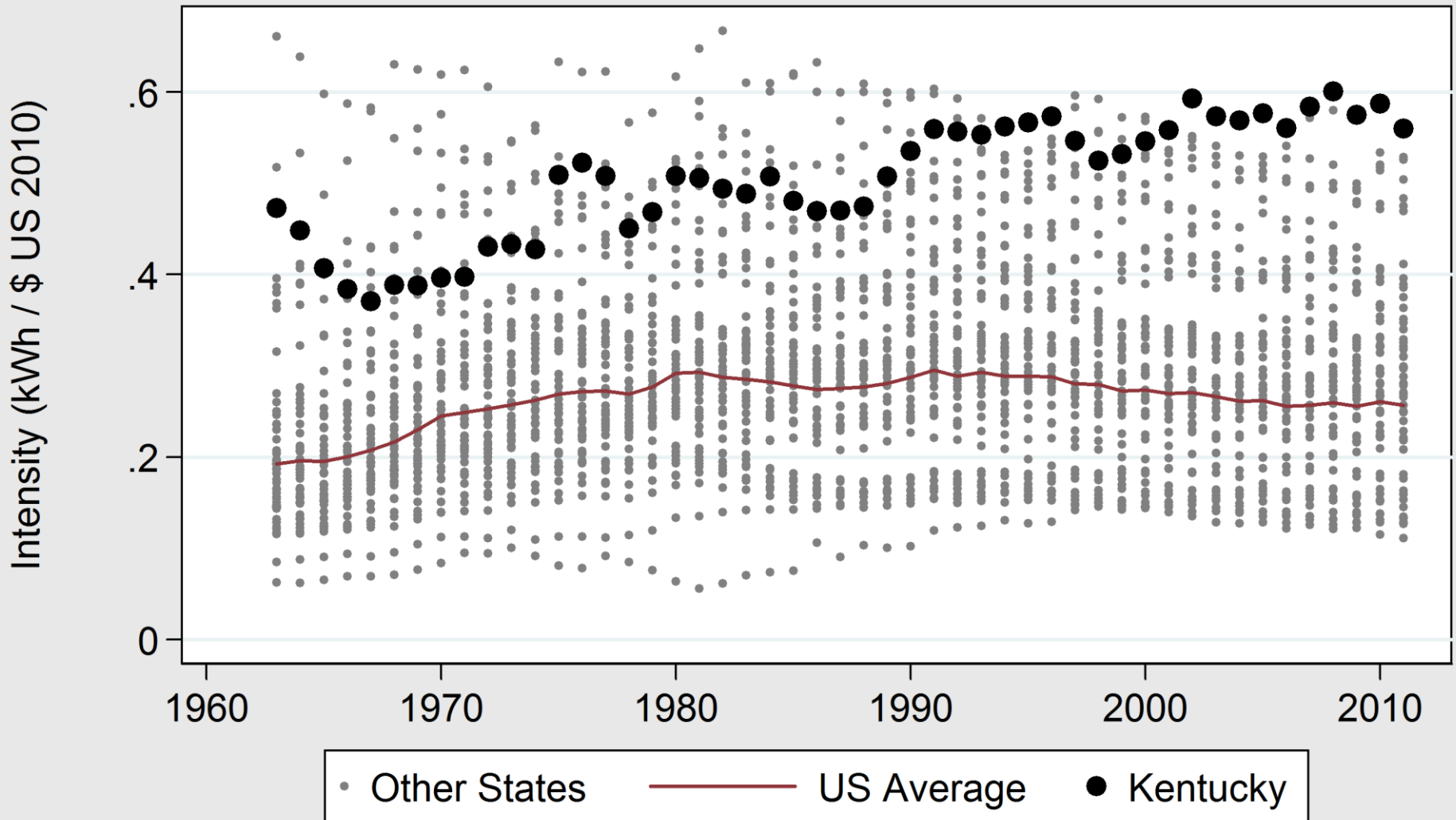


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BLS-CPI

Electricity Consumption per State GDP Dollar, 1963-2011

Kentucky vs. the United States

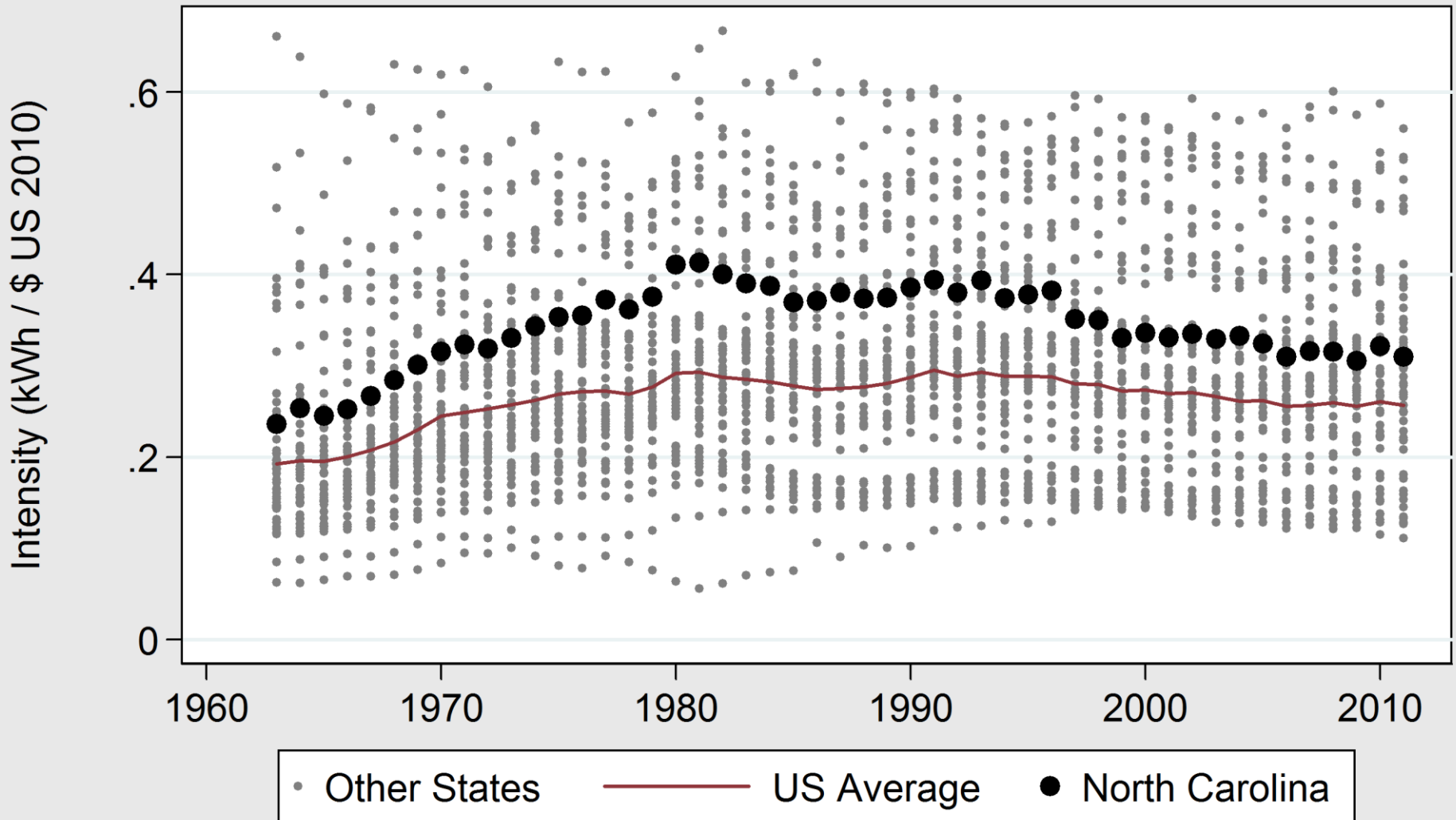


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

Electricity Consumption per State GDP Dollar, 1963-2011

North Carolina vs. the United States

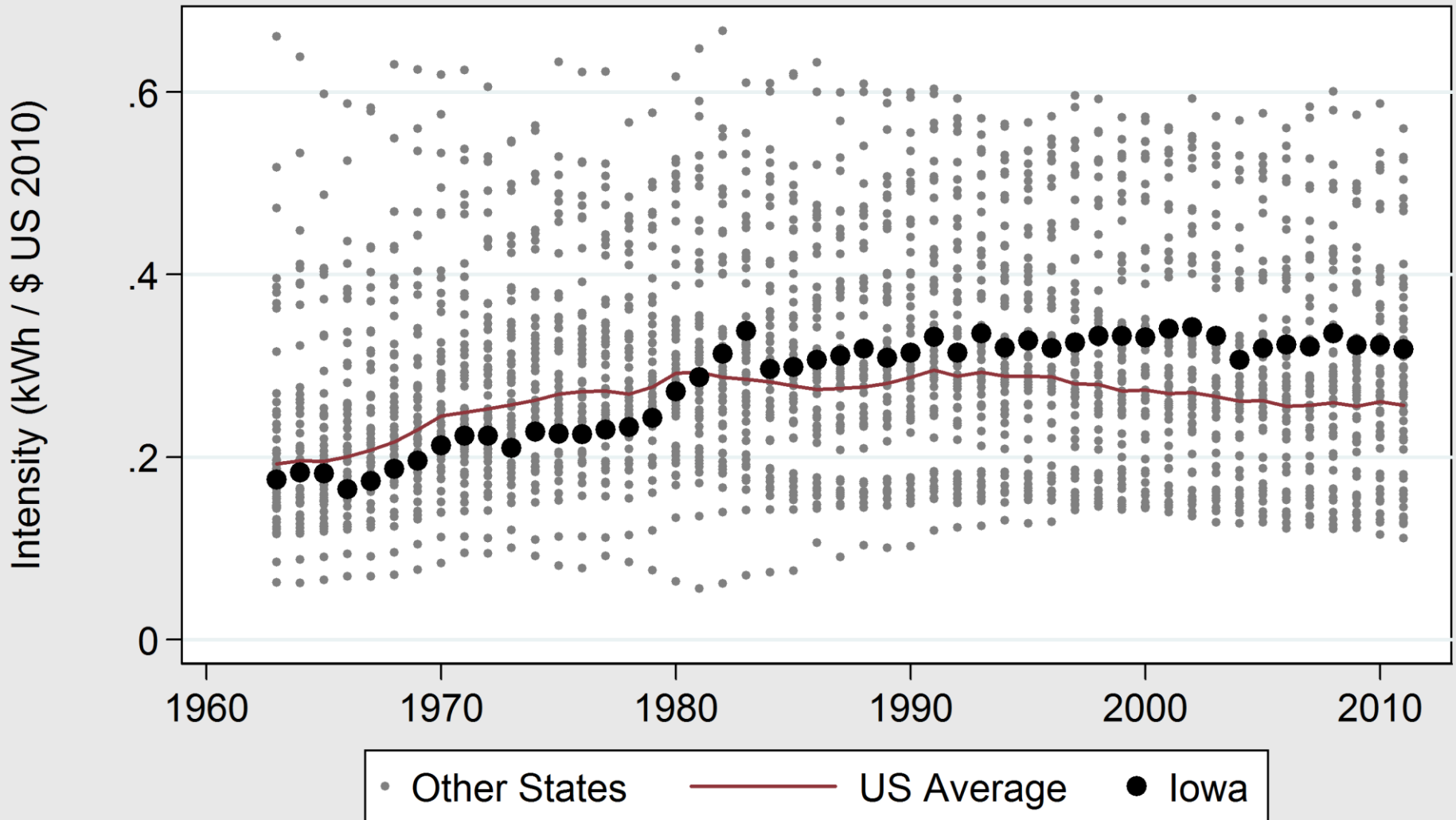


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

Electricity Consumption per State GDP Dollar, 1963-2011

Iowa vs. the United States

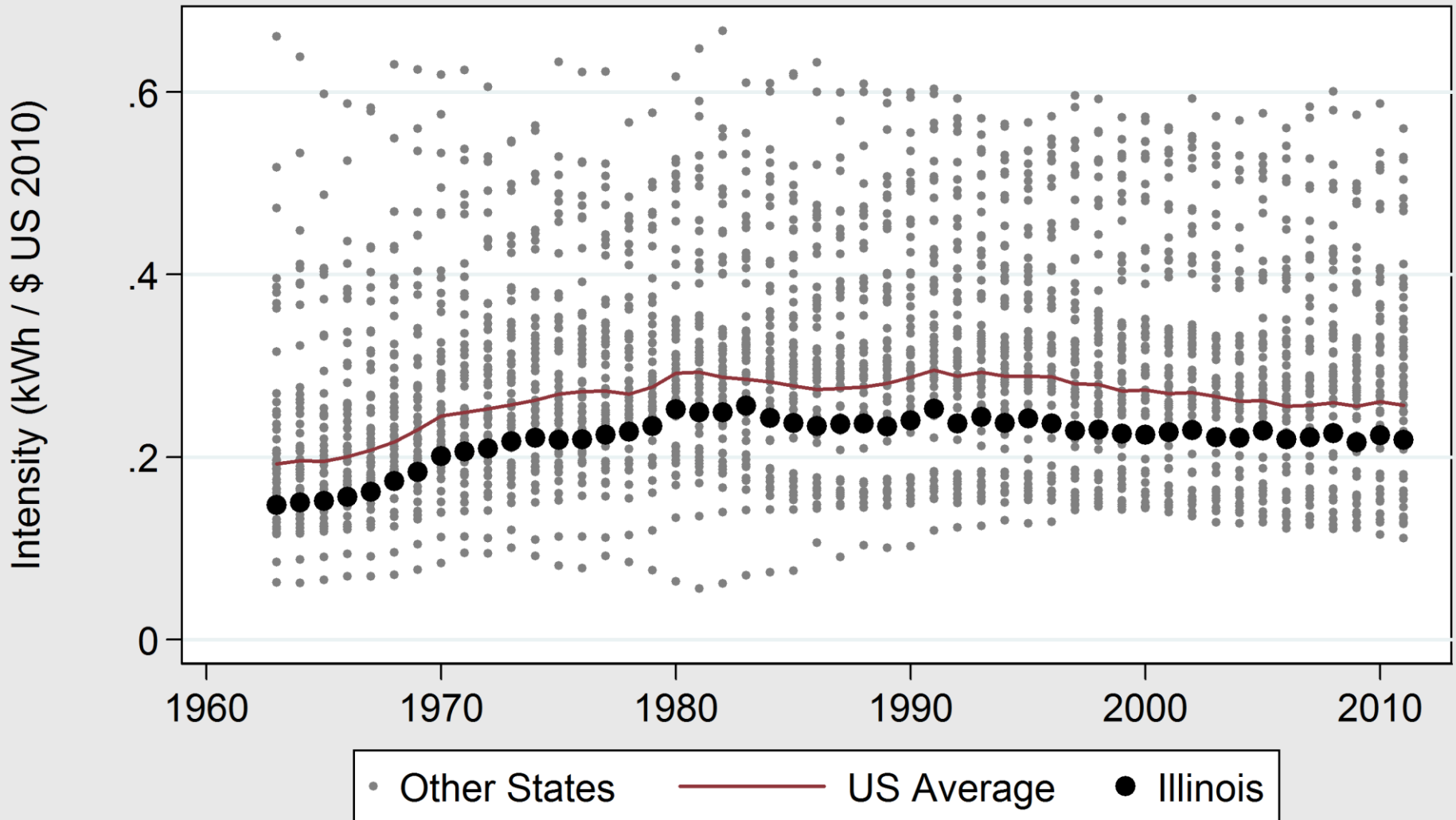


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

Electricity Consumption per State GDP Dollar, 1963-2011

Illinois vs. the United States

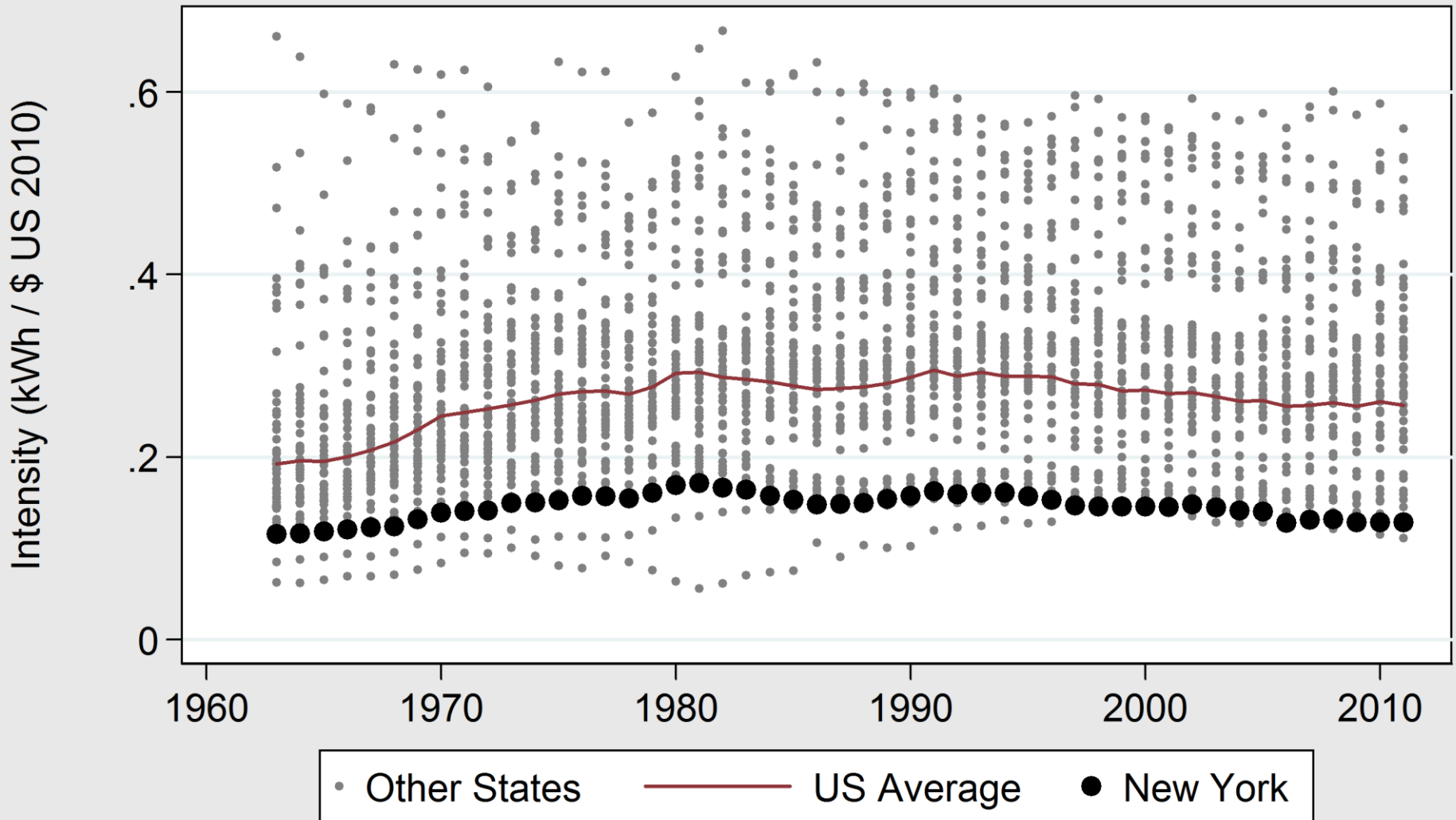


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

Electricity Consumption per State GDP Dollar, 1963-2011

New York vs. the United States

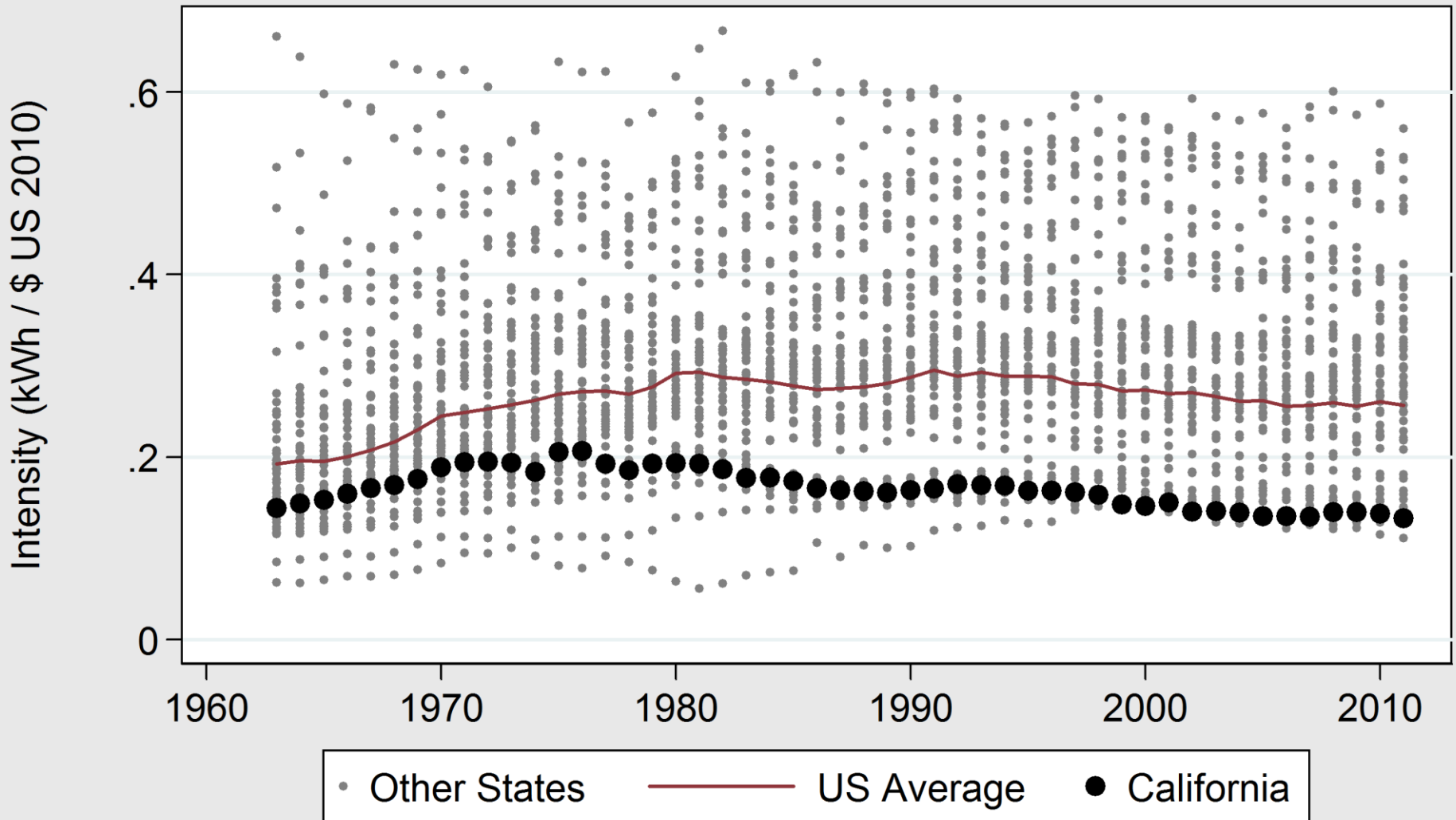


Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

Electricity Consumption per State GDP Dollar, 1963-2011

California vs. the United States



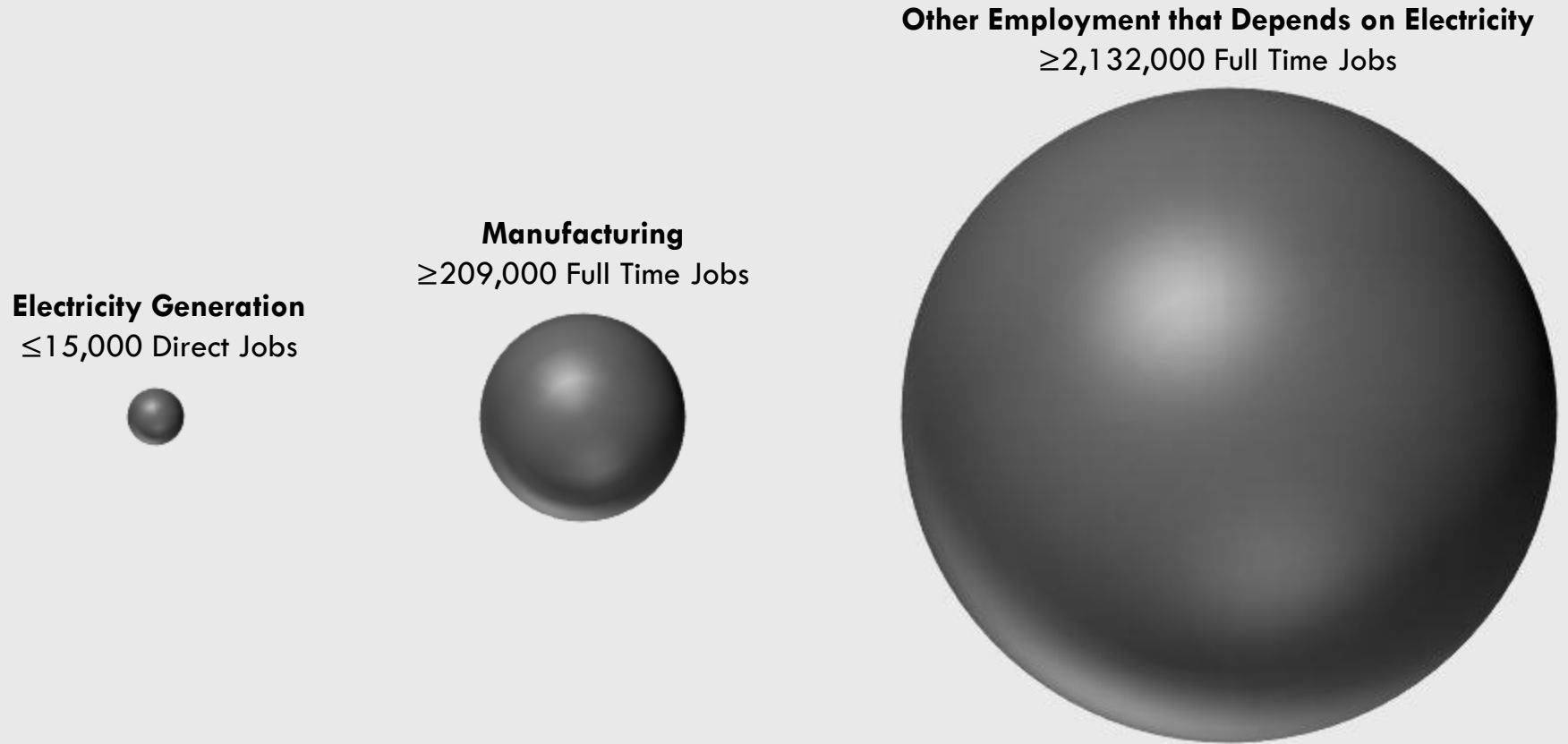
Kentucky Energy Database, EEC-DEDI, 2013

Data Source: EIA Form 861 & 826 & BEA

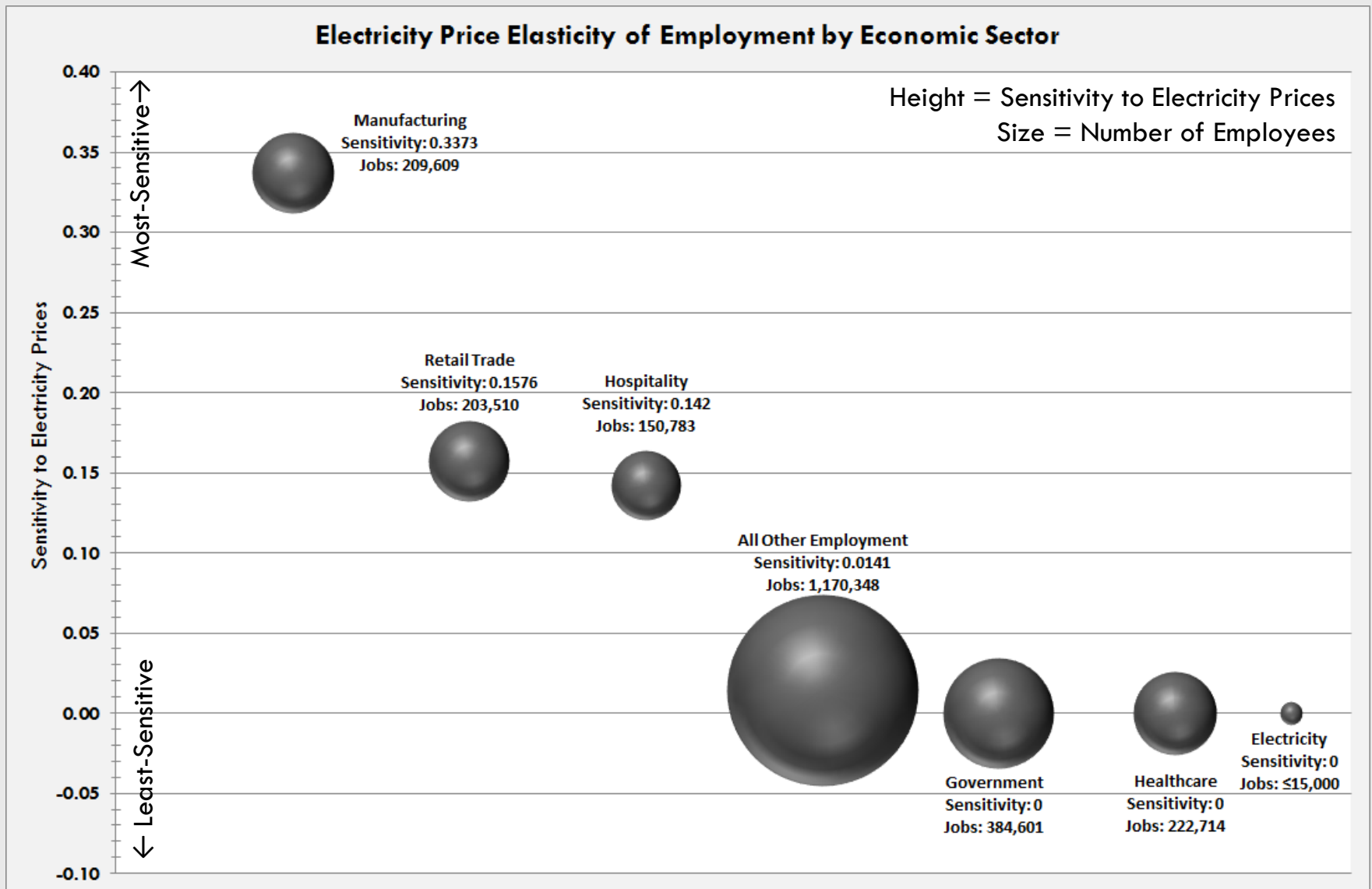
Model Analysis

Electricity Portfolios and Employment

Kentucky Electricity Portfolio & Employment



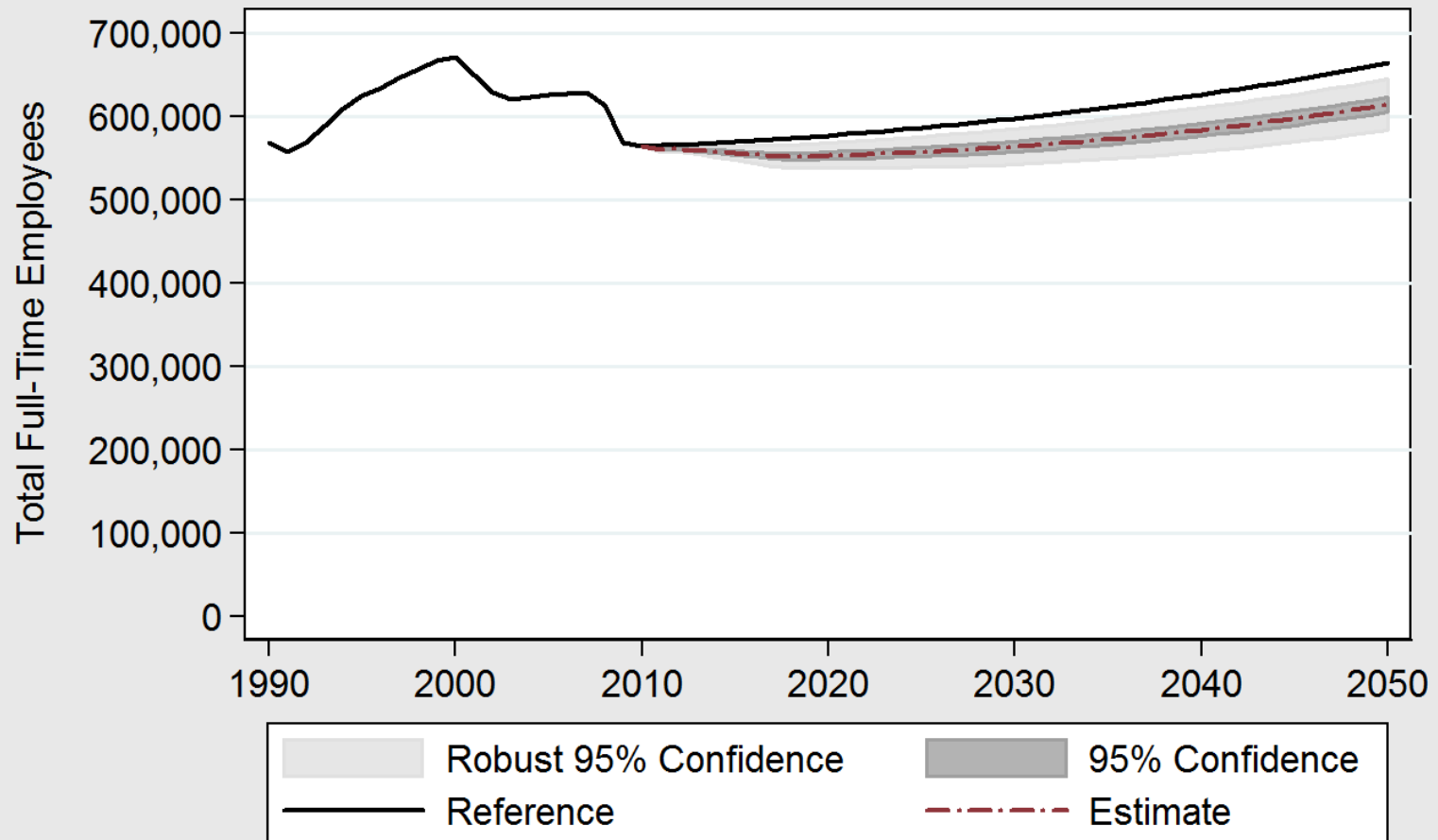
Employment Depends Upon Electricity – Direct employment for electricity generation, such as power plant operators and coal miners, is a relatively smaller portion of total employment in Kentucky compared to the millions of jobs that depend upon the reliable and inexpensive electricity they produce. Electricity-dependent jobs can be modeled with electricity price elasticity of employment coefficients.



Sensitivity to Electricity Prices Differs by Industry – This study developed price elasticity of employment coefficients for the top five employment sectors in Kentucky by modeling the historical responsiveness of employment nationally. Manufacturers were the most-responsive. Retail stores, restaurants, and hotels were less than half as responsive. Government and healthcare showed no responsiveness whatsoever.

Kentucky Electricity Intensive Employment Forecast, 1990-2050

Impact of 25% Electricity Price Increase on Energy Intensive Employment (NAICS 31, 32, 33, 44, 72)

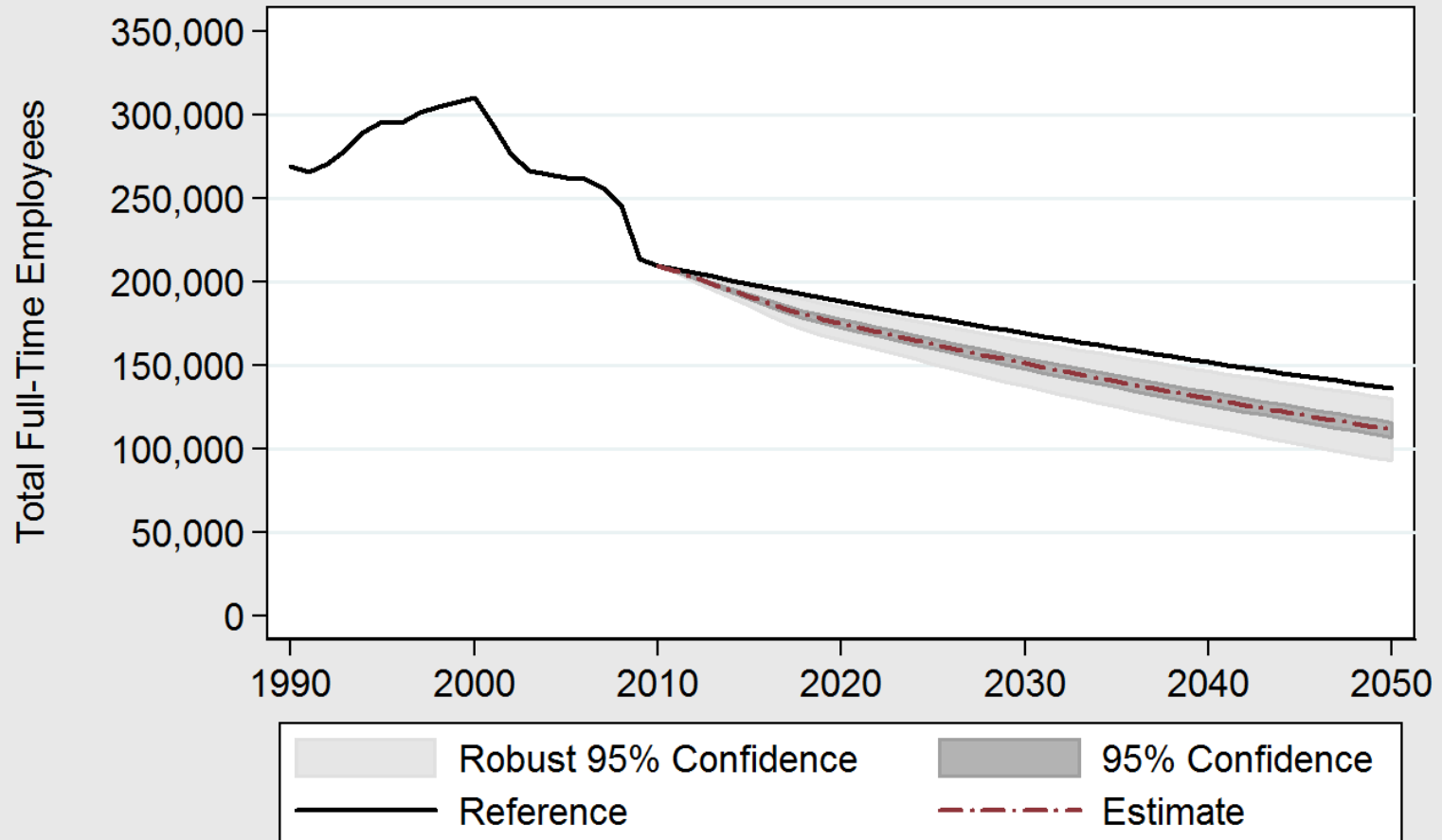


Kentucky Energy Database, EEC-DEDI, 2011

Combined Impact of Electricity-Intensive Sectors - Given a 25% increase in real electricity prices by 2025, Kentucky's most electricity-intensive economic sectors, (manufacturing, retail trade, restaurants, and hotels) could be expected to shed a combined total of **30,237** full-time jobs and with 95% confidence and robust standard errors between **12,620** and **50,947**.

Kentucky Manufacturing Employment Forecast, 1990-2050

Impact of 25% Electricity Price Increase on Manufacturing Employment (NAICS 31, 32, 33)

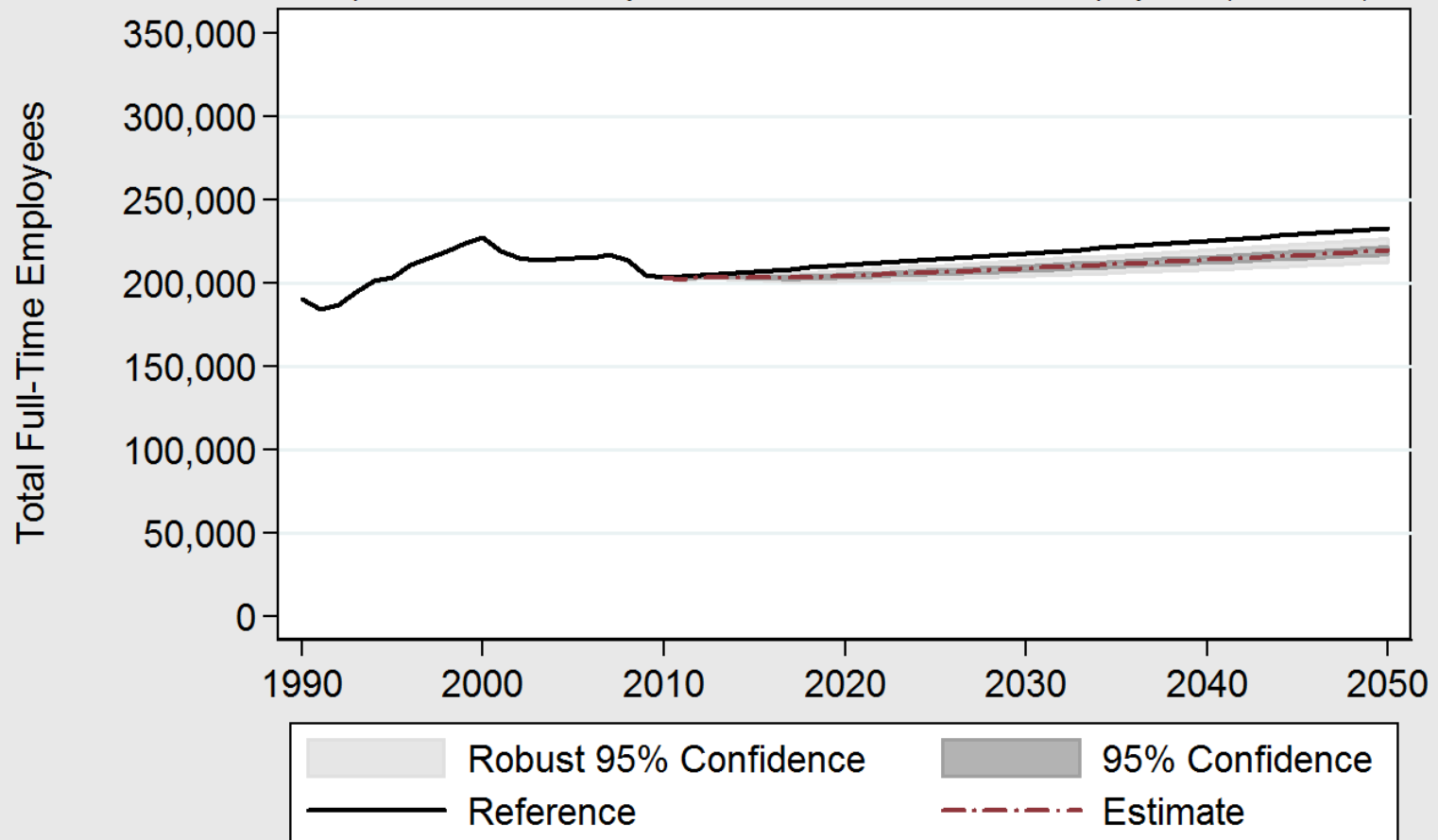


Kentucky Energy Database, EEC-DEDI, 2011

Manufacturers are the Most-Responsive to Electricity Prices - Given a 25% increase in real electricity prices by 2025, manufacturing establishments in Kentucky would be expected to permanently shed an additional **17,660** full-time jobs long-run as a direct result of price increases, and with 95% confidence using robust standard errors between **5,764** and **31,022** full-time jobs, *ceteris paribus*.

Kentucky Retail Trade Employment Forecast, 1990-2050

Impact of 25% Electricity Price Increase on Retail Trade Employment (NAICS 44)

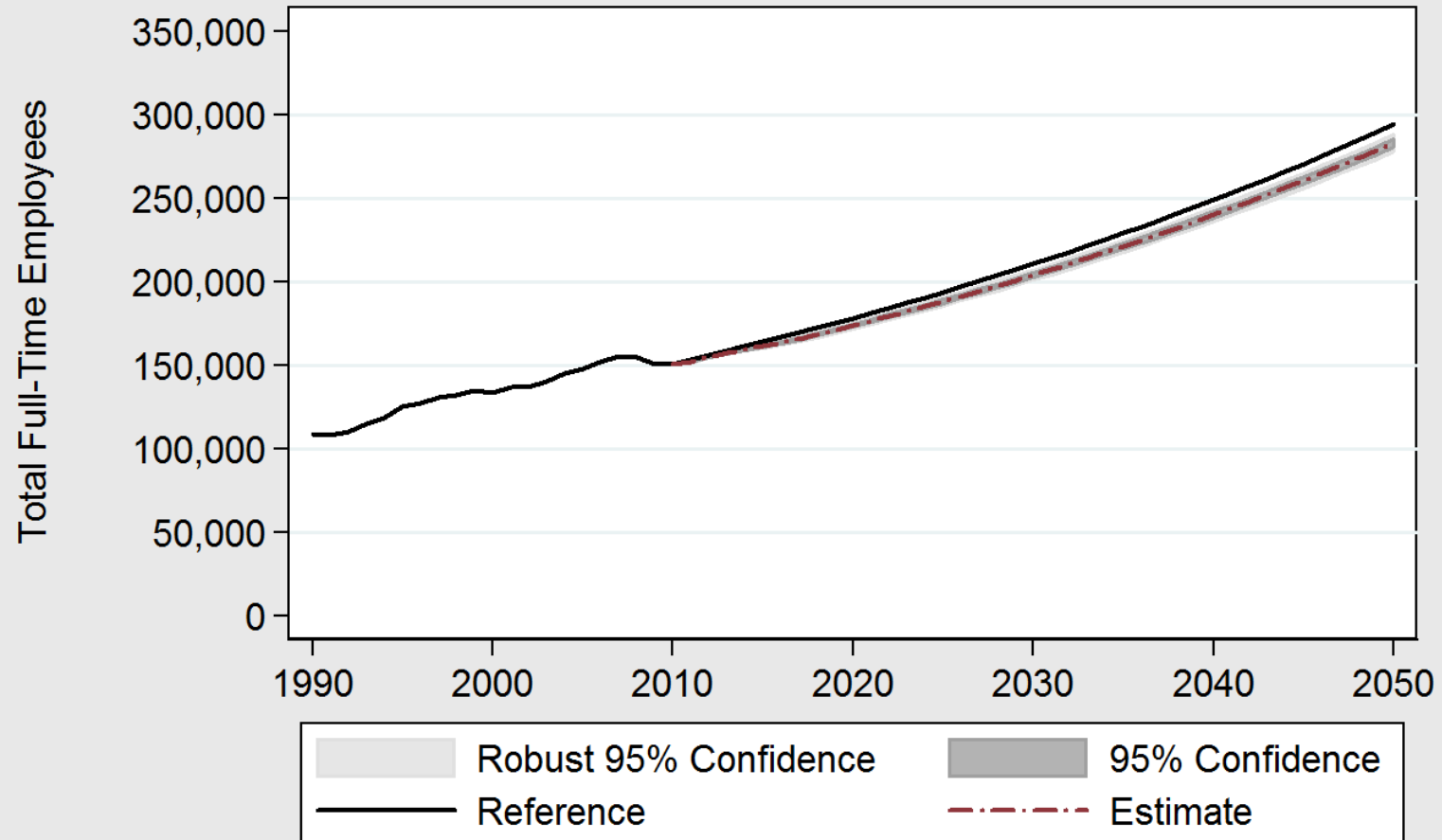


Kentucky Energy Database, EEC-DEDI, 2011

Retail Stores are Much Less Responsive - Given a 25% increase in real electricity prices by 2025, retail establishments in Kentucky would be expected to fail to create **7,225** full-time jobs long-run, and with 95% confidence using robust standard errors, between **3,916** and **12,160** full-time jobs, *ceteris paribus*.

Kentucky Hospitality Employment Forecast, 1990-2050

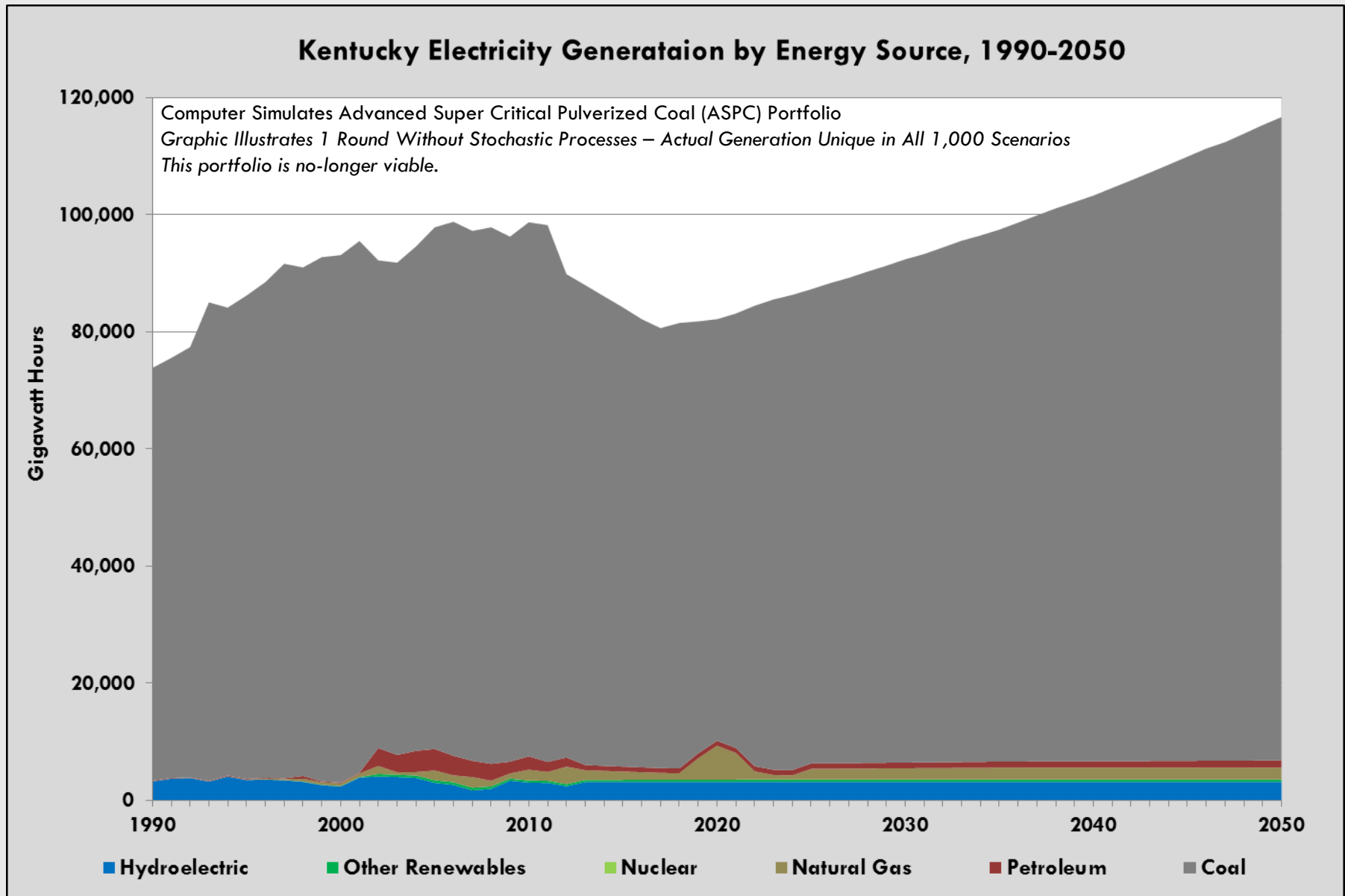
Impact of 25% Electricity Price Increase on Restaurants and Hotels (NAICS 72)



Kentucky Energy Database, EEC-DEDI, 2011

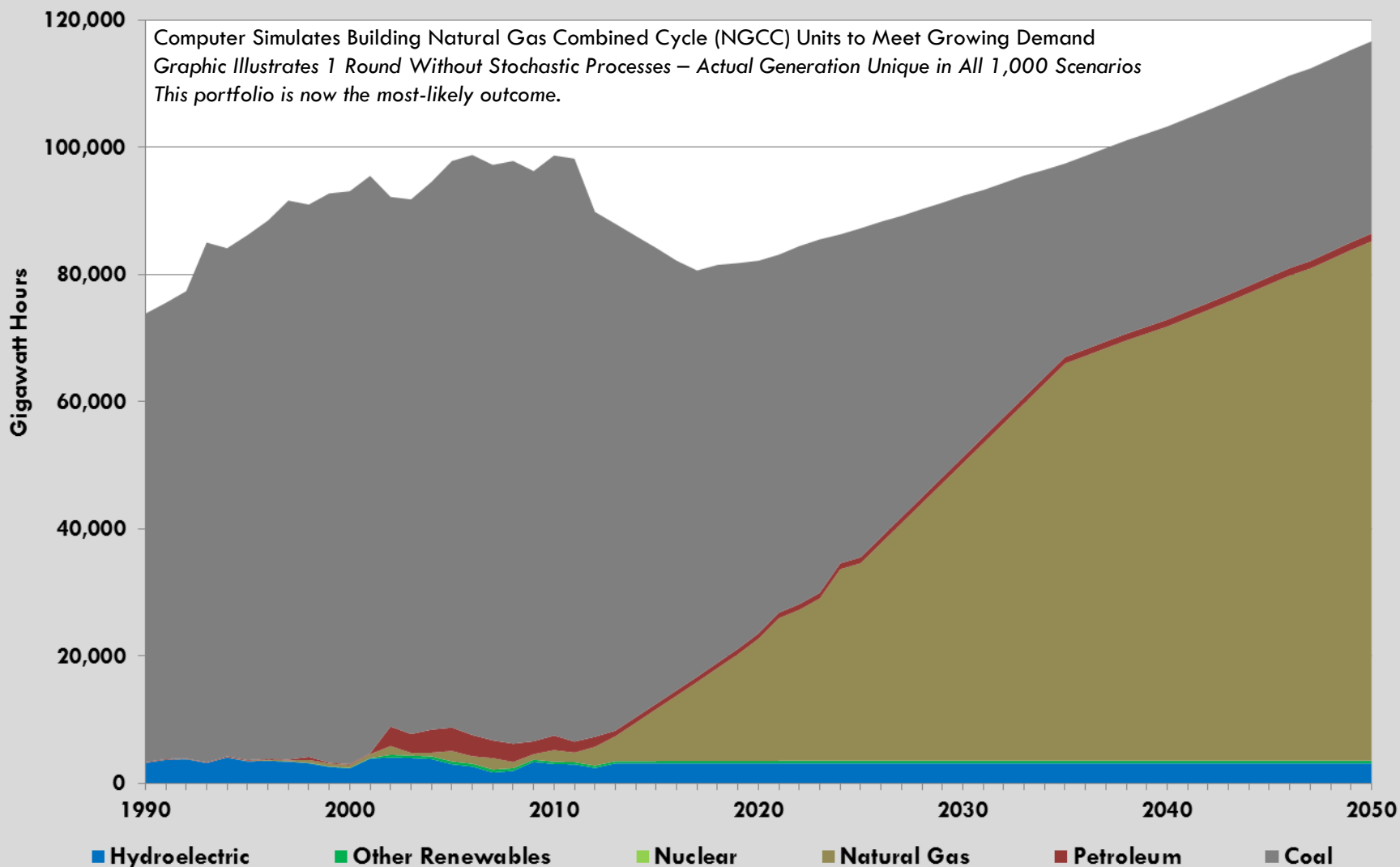
Restaurants and Hotels are Even Less Responsive - Given a 25% increase in real electricity prices by 2025, restaurants and hotels in Kentucky would be expected to shed **5,352** full-time jobs long-run, and with 95% confidence using robust standard errors, between **2,940** and **7,765** full-time jobs, *ceteris paribus*.

Coal Portfolio

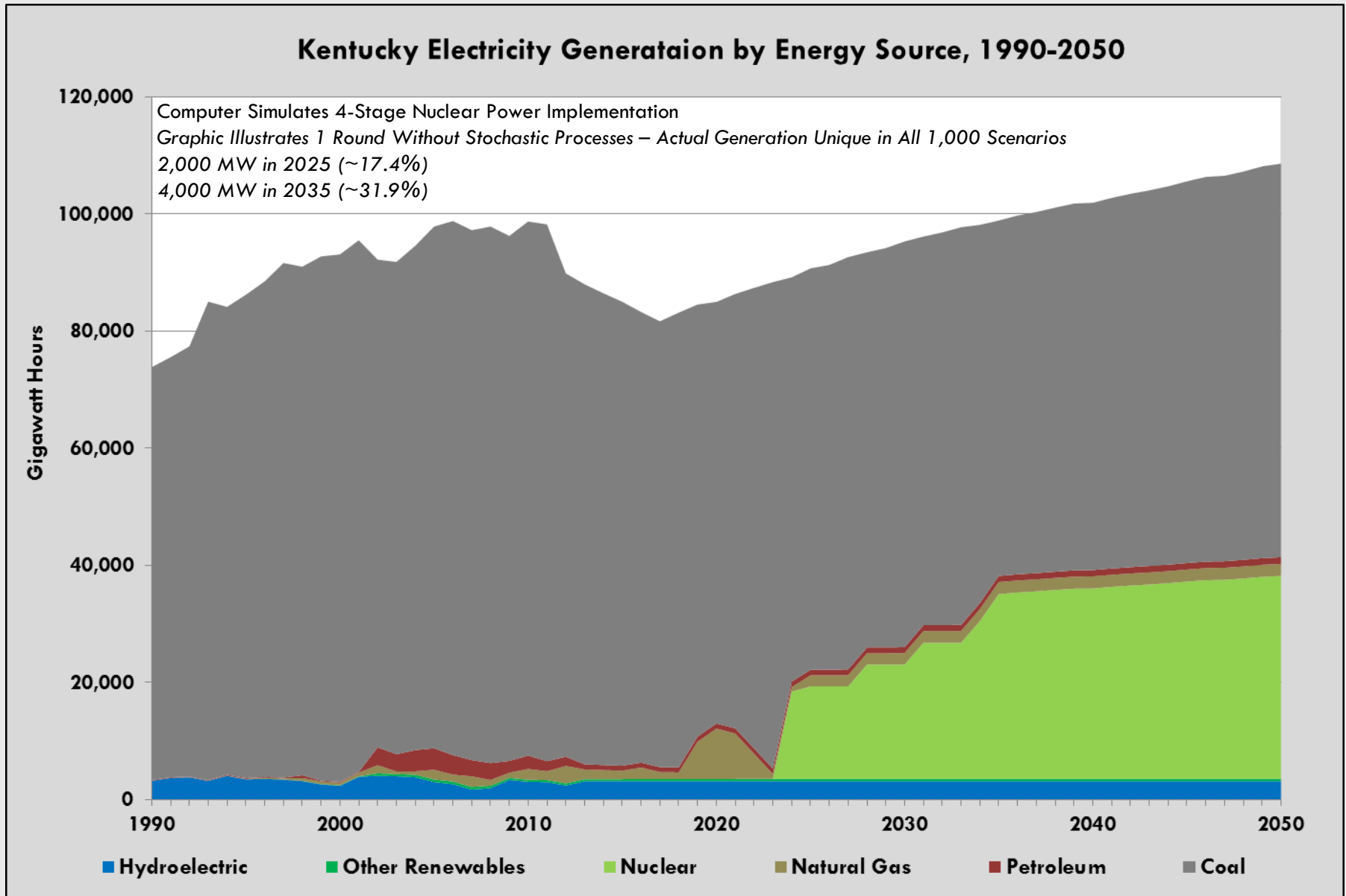


Natural Gas Portfolio

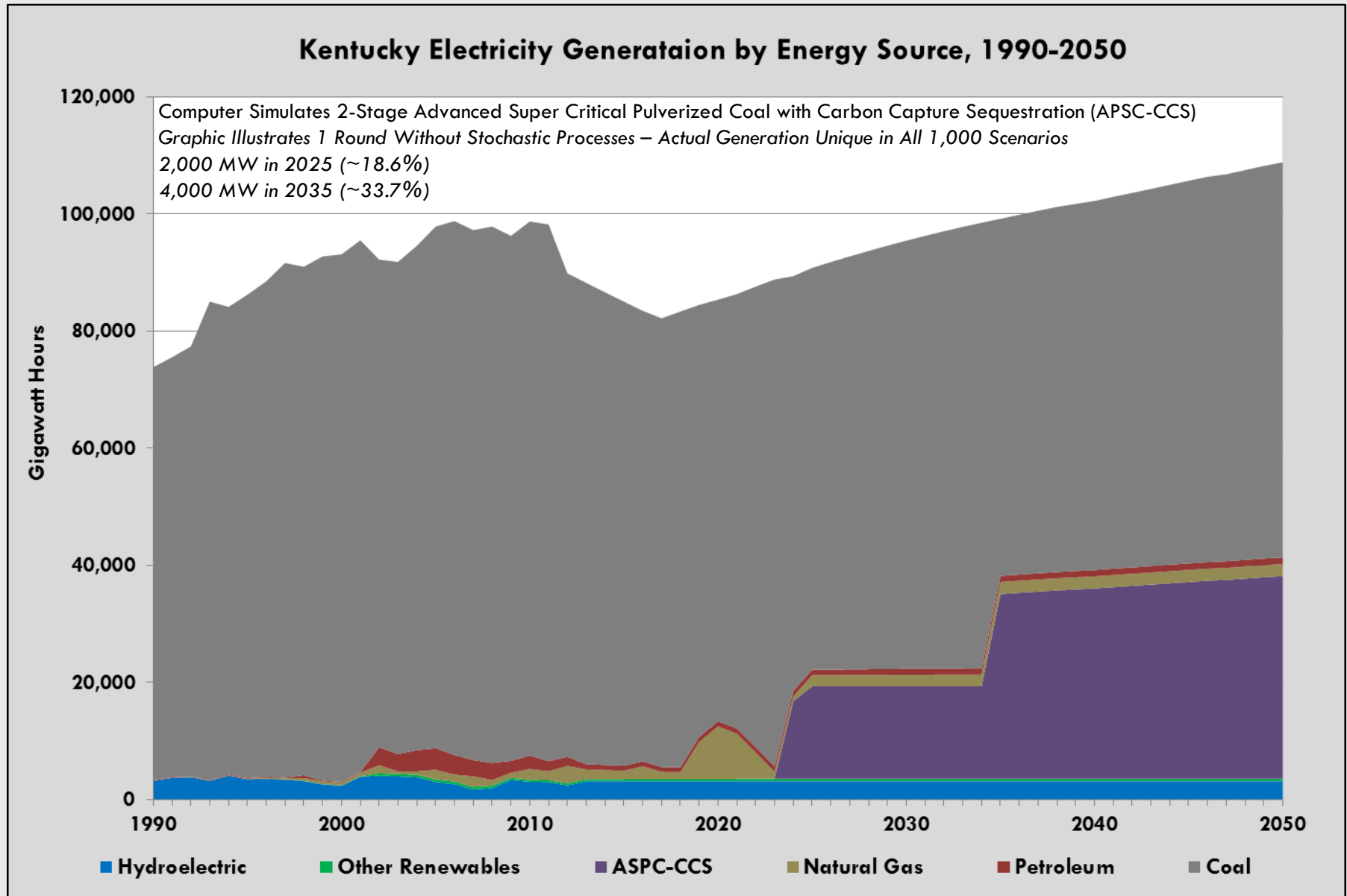
Kentucky Electricity Generation by Energy Source, 1990-2050



Nuclear Portfolio

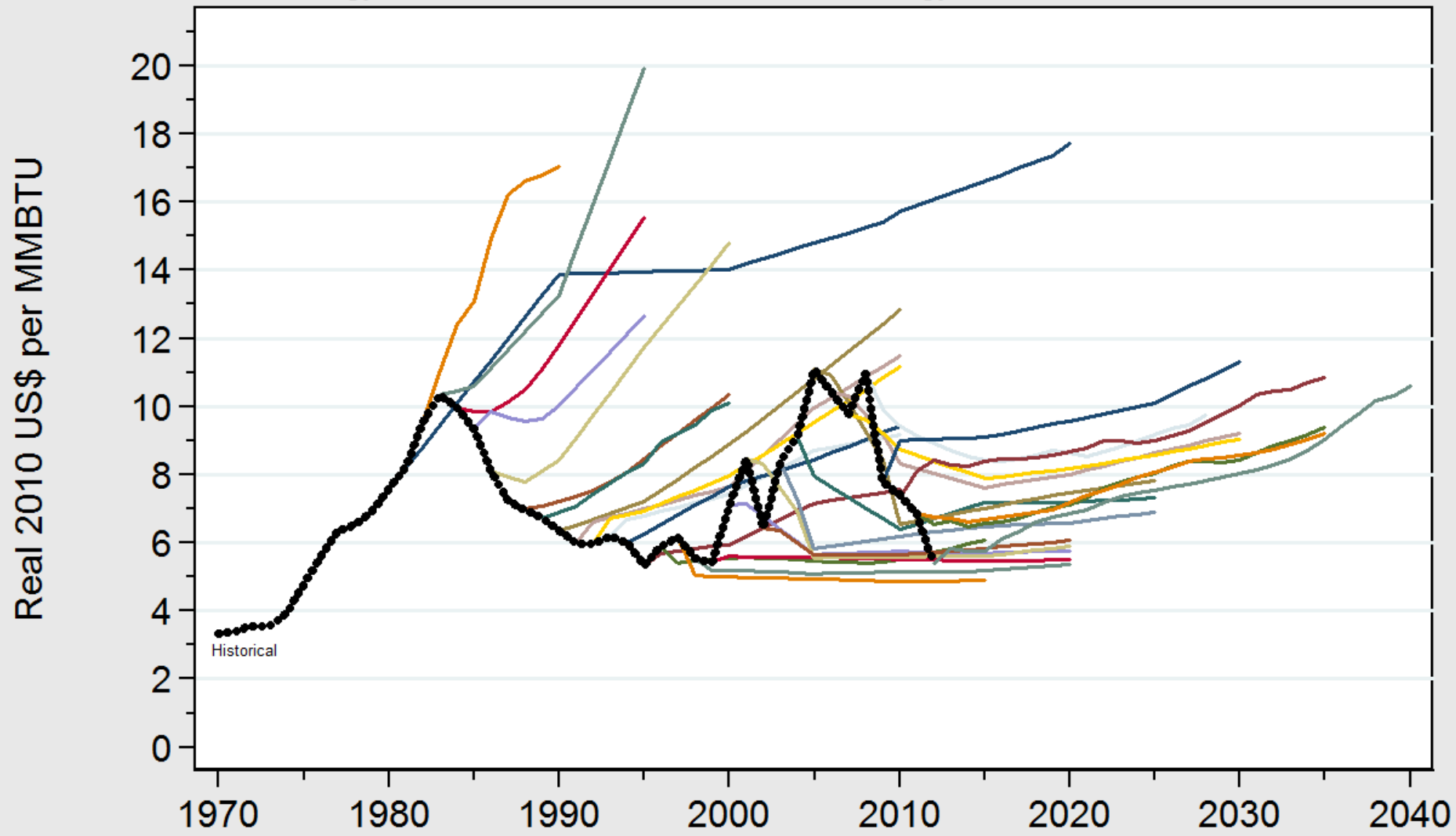


Coal with Carbon Capture Sequestration Portfolio



EIA Natural Gas Price Forecasts, 1979-2013

Energy Information Administration Annual Energy Outlook Forecasts vs. Actual

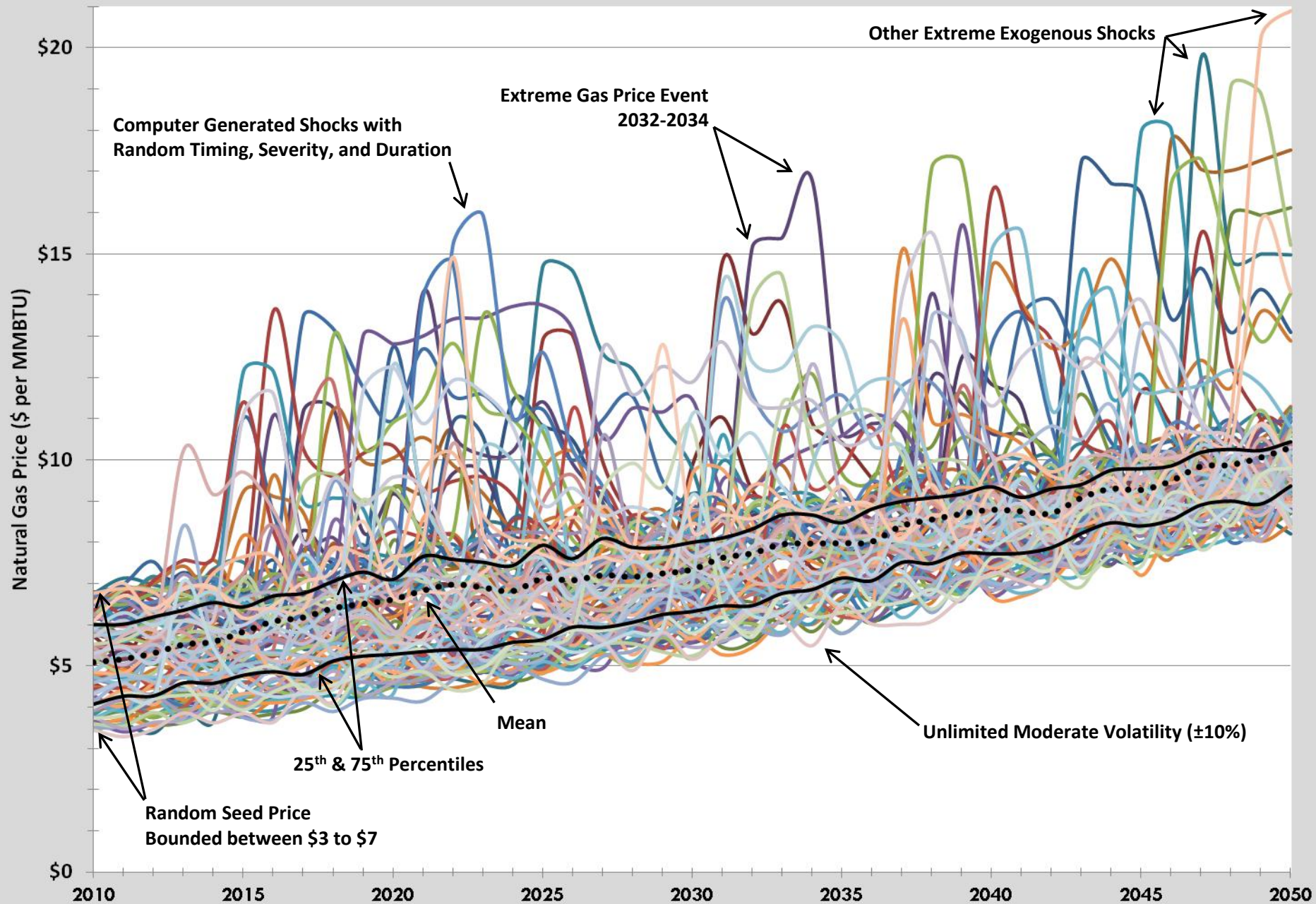


Kentucky Energy Database, EEC-DEDI, 2013

Data Sources: EIA-AEO 1979-2013 - Reference Case Delivered Price - All Sectors & BLS-CPI, 2013

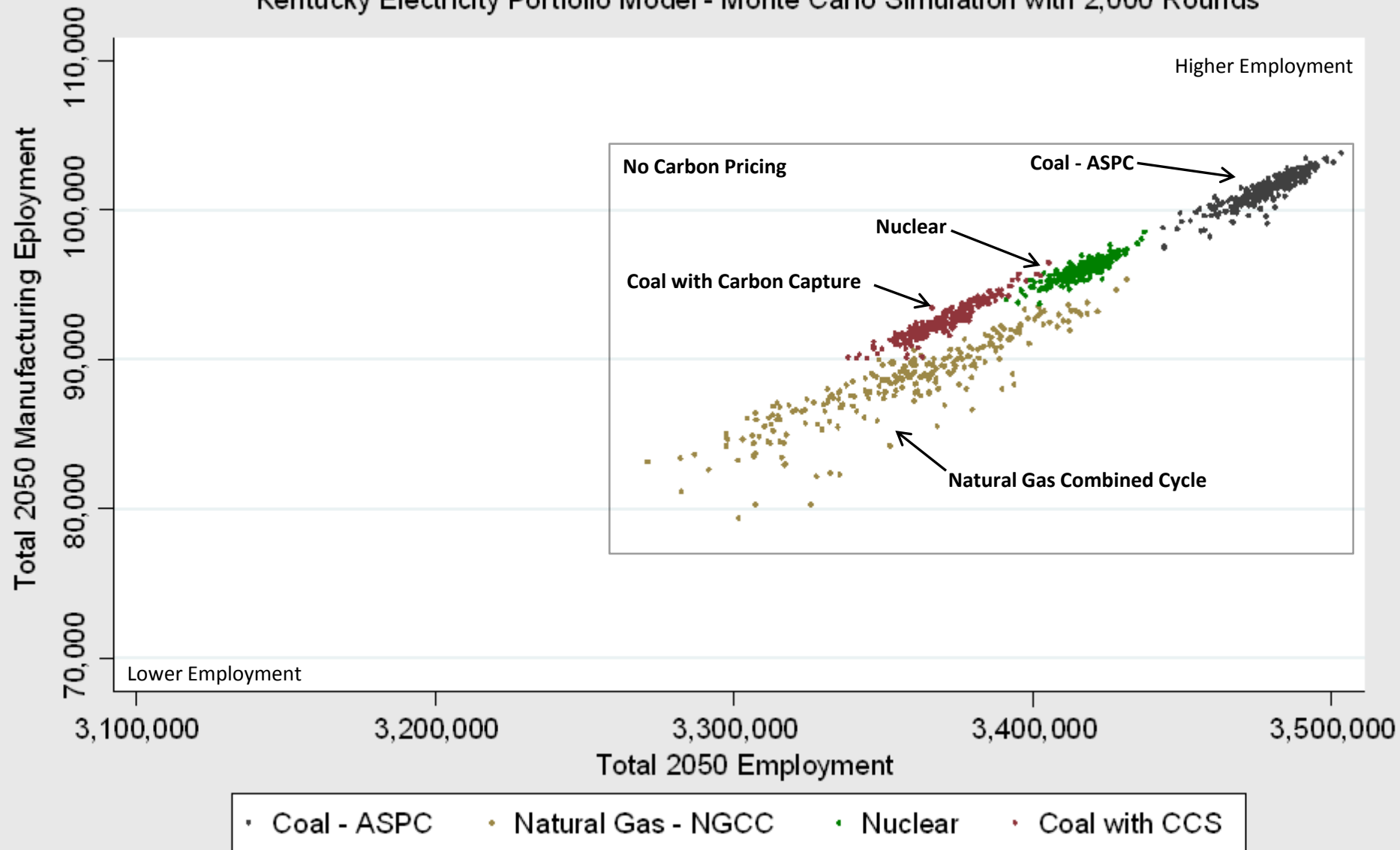
Stochastic Natural Gas Price Input Assumptions, 2010-2050

Kentucky Electricity Portfolio Model - Monte Carlo Simulation with 100 Rounds



Kentucky Employment Response to Electricity Generating Portfolios, 2050

Kentucky Electricity Portfolio Model - Monte Carlo Simulation with 2,000 Rounds

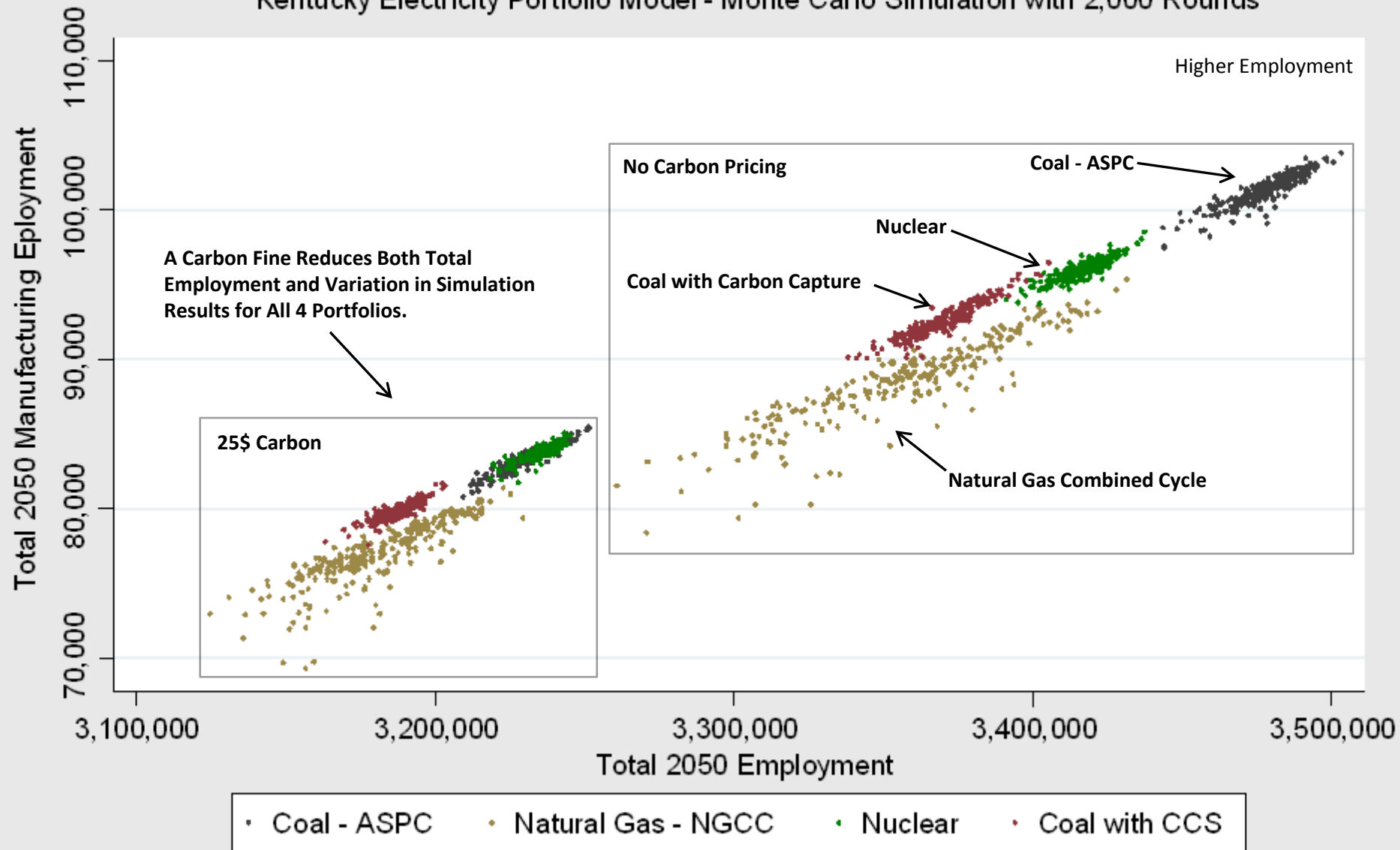


Kentucky Energy Database, EEC-DEDI, 2012

Total employment includes retail, manufacturing, hospitality, healthcare, government, and "all other" as well as direct employment from electricity generation including coal miners and power plant operators.

Kentucky Employment Response to Electricity Generating Portfolios, 2050

Kentucky Electricity Portfolio Model - Monte Carlo Simulation with 2,000 Rounds

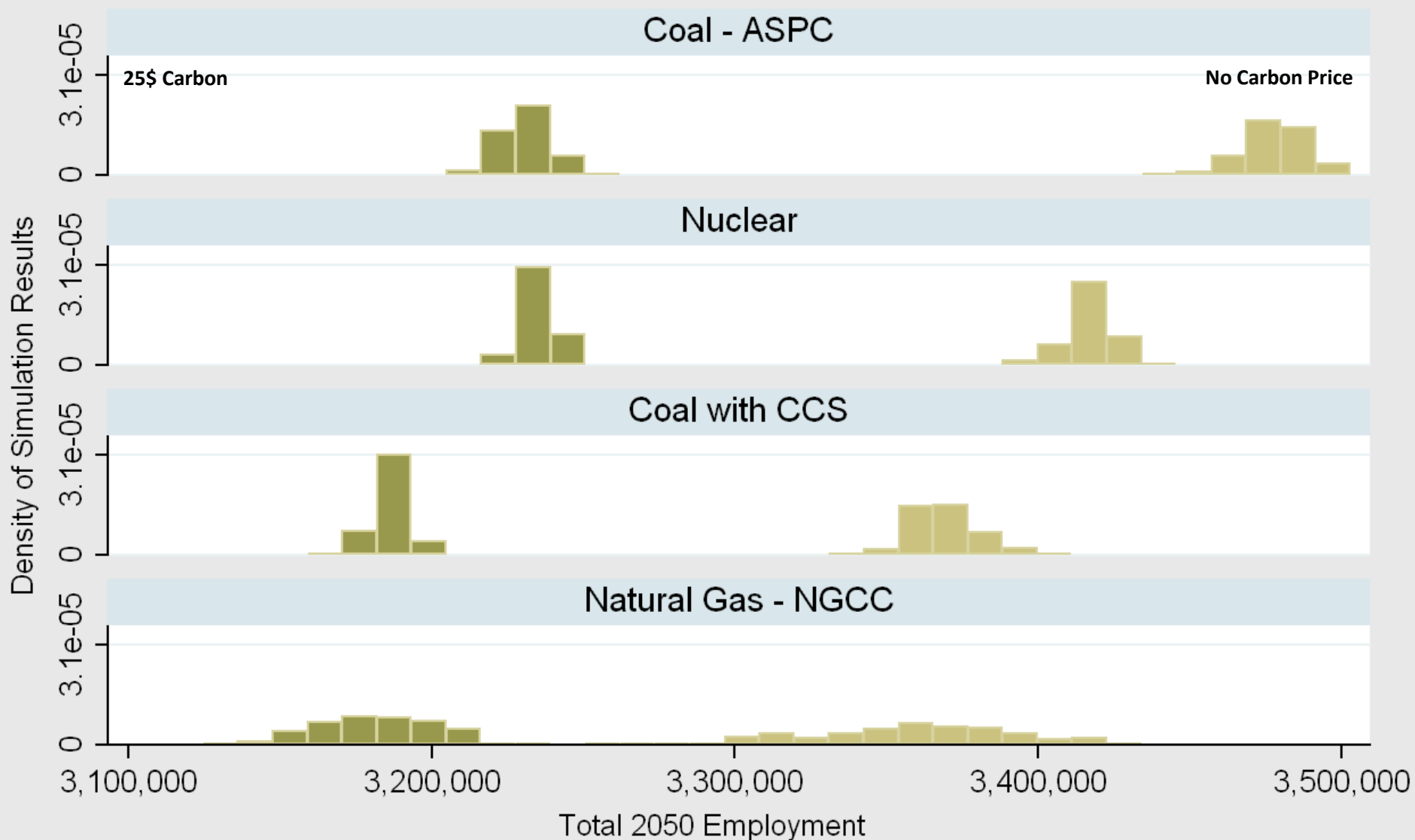


Kentucky Energy Database, EEC-DEDI, 2012

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Kentucky Employment Responsiveness to Electricity Generating Portfolios

Kentucky Electricity Portfolio Model - Monte Carlo Simulation with 2,000 Rounds



Kentucky Energy Database, EEC-DEDI, 2012

Conclusion

Concluding Remarks

- **Electricity costs and reliability are important factors for manufacturing-intensive economies.**
- **In manufacturing-intensive economies, considerations for base-load generation dominate.**
- **Current and pending policies, along with societal concerns, are limiting base-load generation options.**
- **The US is moving toward a single base-load generation option.**
- **Price elasticity of employment should be taken into consideration, when trying to understand such impacts.**

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Appendix

Analytical Methodology

A multiple regression of panel data model using fixed effects was estimated for each of the top five employment opportunities in Kentucky, both with and without robust standard errors, for a total of ten models. Fixed effects were used to control for the numerous factors inherently affecting sector-specific employment as well as electricity prices from state to state that have not been accounted for in the independent variables included in this study. The result is a conservative estimate of the isolated national effect of the variable of interest, real electricity prices on employment by industry.

The multiple regression of panel data model with fixed effects can be generally given by,

Predicted Employment by Industry in State (i) and Time (t)

$$Y_{it} = \beta_0 + \sum_{j=1}^{k-1} \beta_j X_{jit} + \alpha_i + \varepsilon_{it}$$

Stochastic Error Term ($\sim N(0, \sigma^2)$)

Constant Intercept Across States

Sum of the product of the observation for each independent variable j through k for state i in year t and the coefficient of X_j

Fixed Effect for State (i)

Where i and t index states and years, such that y_{it} is the dependent variable of interest, employment by industry, in state i in year t , β_0 is the constant y intercept across all states, X is a k by 1 vector of explanatory variables, $\beta_j X_{jit}$ is the product of the observation for each independent variable j through k for state i in year t and the coefficient of X_j , k is the total number of included independent variables, α_i is the time-invariant fixed effect for state i , and ε_{it} are the residuals, and where $\varepsilon_{it} \sim N(0, \sigma^2)$, or are approximately normally distributed with a mean of zero.

Model of Electricity Prices & Employment by Sector

Logged Variables	Manufacturing Employment	Retail Employment	Hospitality Employment	Healthcare Employment	Government Employment
Price of Electricity (Real 2010 US\$)	-0.337 *** (-0.0307)	-0.158 *** (-0.0136)	-0.142 *** (-0.0152)	-0.0426 ** (-0.0158)	0.00084 (-0.0101)
Educational Attainment	0.0249 (-0.146)	-0.108 (-0.065)	-0.0679 (-0.0728)	-0.536 *** (-0.0758)	-0.14 ** (-0.0482)
State GDP (Real 2010 US\$)	0.744 *** (-0.0514)	0.509 *** (-0.0228)	0.318 *** (-0.0255)	0.17 *** (-0.0265)	0.253 *** (-0.0169)
Population	0.166 ** (-0.0532)	0.26 *** (-0.0236)	0.129 *** (-0.0264)	0.37 *** (-0.0275)	0.258 *** (-0.0175)
Year	-76.05 *** (-5.536)	-11.31 *** (-2.457)	21.11 *** (-2.752)	55.21 *** (-2.861)	3.801 * (-1.819)
Constant	579.4 ** (-41.38)	88.85 *** (-18.36)	-153.9 *** (-20.57)	-413.5 *** (-21.39)	-22.72 (-13.6)
R-Squared	0.7776	0.956	0.9219	0.8885	0.9344
Observations (N x t)	1069	1071	1069	1071	1071
Number of States (N)	51	51	51	51	51

Standard Errors in Parentheses

Asterisk Denotes Statistical Significance at the Following Levels: * p<0.05, ** p<0.01, *** p<0.001

All variables were transformed to their natural logarithms, such that their coefficients may be interpreted as elasticities.